

IN THE SPECIFICATION

This is not a replacement specification, only amended sections of the specification are presented. All other sections remain as originally filed.

page 1, line 6:

The present invention relates to an ultrasonic transducer on a flexible substrate, particularly to a ~~micro~~ microelectromechanical (MEMS) ultrasonic transducer on a flexible substrate with enhanced emission and reception of ultrasonic waves, which, by increasing an effective transmission area, improves coupling to air, ~~reducing and reduces~~ reduces attenuation. This, in turn, provides for high responsiveness to frequency changes, effective energy transformation and detecting speed, allowing ~~various~~ an increased range of sound speeds, geometrical shapes and focal lengths for a wide range of applications.

2. Description of Related Art

~~Conventional ultrasonic~~ Ultrasonic transducers transform electrical energy into mechanical energy, having a sensor head emitting an elastic wave into a bulk body and receiving back an elastic wave, which has been reflected at an internal surface.

Ultrasonic sensors are widely used central components of ultrasonic detectors. Ultrasonic detectors are undergoing the current trend of ~~miniaturisation~~ minituration, which offers the advantages of high response, high resolution and a wider range of applications. A conventional ultrasonic detector depends for functioning on proper coupling. ~~Mostly~~ In most cases a coupling medium is required, ~~like~~ with conventional ultrasonic detectors this is usually a liquid or a solid body. If air is used as a coupling medium with a conventional ultrasonic detector, a layer glued on a back side and an adaptive layer have to be incorporated into the design. ~~Current~~ Variable characteristics of air also have an influence on the ~~properties~~ performance of the sensor. For transmission on curved surfaces, Snell's law has to be taken into account, which describes intensities of the original, the reflected and the transmitted waves depending on the incidence angle. On curved surfaces, effective inspection areas are thereby ~~possibly diminished~~ often limited, and

long paths of detected waves result in decreased signals and increased variable conditions of air coupling, as shown in Fig. 5. Furthermore, upon a curved surface with an inclined direction of incidence, as shown in Figs. 6 and 7, a larger inclination angle θ of the transmitted wave results in further reduced transmission, distorting measurement results, possibly to the point of no detection of signals. Therefore, for good resolution and stability, it is ~~indispensable~~ advantageous to develop a transducer which is effective at surfaces bordering air and overcomes the problem of insufficient transmission on curved surfaces.

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~~Transmissibility~~ Transmission of ultrasonic waves at the ~~couplant of~~ interface between liquid and solid bodies is influenced by temperature, pressure, density and velocities of particles, which can limiting the range of ultrasonic applications. With ~~changed~~ a non-uniform air coupling medium, ~~for with~~ the mismatch of transducer impedance, intensities of waves, as well as, frequency responses, band width, and directionality are reduced, hampering sensor functions. Furthermore, curved surfaces result in further reductions of transmission of waves.

~~Presently~~ To date, micro ultrasonic devices are limited of geometry, ~~lead the wave effective transmission are manufactured using~~ hindering the use of micro manufacturing techniques which promise to reduce costs and allow for mass production. ~~Therein~~ In conventional micro manufacturing, silicon is used as a basic material, and a range of complex techniques is employed. ~~Materials~~ The silicon-based materials used are brittle and are not readily formed into required shapes, so that ultrasonic intensities and ~~efficient~~ efficiencies do not reach anticipated values. U.S. patent no. 6,328,697B1 discloses an array of ultrasonic detectors 90 having several layers, as shown in Fig. 8. On a base 91 of silicon a surface is built at a low temperature. A support 92 of Si_3N_4 is grown thereon from a PECVD (plasma enhanced chemical vapor deposition) process. After that, material that is not needed is removed, so that a membrane 93 on the support 92 remains. A lower electrode is formed by the conductivity of the silicon base 91, and an upper electrode 94 of aluminum is grown

on the membrane 93 from vapor, forming a protective layer. A characteristic of this device, however, lies in using silicon as material of the base and thereby using a hard rigid material for the support. Therefore, there is no way to bend the ultrasonic detectors 90. While manufacturing can be performed in an integrated process and adaption (connectivity) is improved, attenuation is high and resolution is reduced, as compared to that obtainable with a device on a flexible base, so there is still a need for improving on the above mentioned problem.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a flexible ultrasonic transducer which is rapidly produced and offers low attenuation and ~~match~~ couples layers with little impairing of transmission. ~~Therein~~ In one preferred embodiment, an array of ultrasonic transducer elements are formed on one surface of a flexible metallic base, each transducer element carries ~~has~~ supports on at least two sides of a cavity, on which and a metallic membrane is ~~laid~~ attached to the top of the supports for performing ultrasonic vibrations. Employing the supports generates a relatively thick insulating layer, simplifying manufacturing. ~~Between~~ With the two metallic electrodes and the intervening cavity thus formed, a larger amount of energy is ~~is~~ may be stored for driving the membrane. The microelectromechanical ultrasonic elements may thereby perform emission and reception of ultrasonic waves with lower attenuation and greater sensor effectiveness. Attenuation is reduced and adaptability is improved, resulting in more effective detection.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic side view of one of the ultrasonic transducer elements of the present invention.

Fig. 2 is a perspective view of the flexible ultrasonic transducer of the present invention.

Fig. 3 is a schematic illustration of adaption and attenuation of ultrasound waves on a curved surface using the present invention.

Fig. 4 is a schematic illustration of angular transmission of ultrasound waves on surfaces using the present invention.

Fig. 5 is a schematic illustration of signal reflections on a curved surface using a conventional ultrasonic transducer.

Fig. 6 is a schematic illustration of adaption and attenuation of ultrasound waves on a curved surface using a conventional ultrasonic transducer.

Fig. 7 is a schematic illustration of angular transmission of ultrasound waves on a curved surface using a conventional ultrasonic transducer.

Fig. 8 is a schematic side view of a conventional ultrasonic transducer element.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in Figs. 1 and 2, the flexible ultrasonic transducer of the present invention comprises a base 10 ~~and~~ with a plurality of ultrasonic transducer elements 1, which in turn comprise: a membrane 20; a plurality of first electrodes 31; and a plurality of second electrodes 32. The base 10 has an upper side 11 and a lower side 12. ~~For each~~ Each ultrasonic transducer element 1, ~~a depression 13 cuts into~~ has a raised support 14 on the upper side 11, ~~with a support 14 set on two lateral sides thereof~~ an internal cavity 13 open at the top. ~~The upper and lower sides 11, 12~~ base 10, and the support 14 are ~~may be~~ made of flexible material or rigid material. ~~For~~ In one preferred embodiment, for each ultrasonic transducer element 1, the base 10 and the support 14 form a single body made of uniform material, e.g., silicon, Si_3N_4 , polysilicon, kapton, nickel, teflon, resin, plastics, polyester, photoresist or polymolecular material. However, in other embodiments, the base and support may be of different materials. The support 14 has an upper end with a upper surface 15. The membrane 20 has an outer side 21 and an inner side 22, which is placed on the top side 15 of the support 14. By combining a plurality of ultrasonic transducer elements 1 on an extended base 10 the flexible ultrasonic transducer of the

present invention is formed. The plurality of first and second electrodes 31,32 are made of gold, silver, nickel, aluminum and copper, for example. At the location of each ultrasonic transducer element 1, one of the plurality of first electrodes 31 is ~~inserted~~ positioned between the upper and lower ~~sides~~ surfaces 11,12 of the base 10. If the base 10 is made of electricity conducting material, the first electrode 31 is not needed and dispensed with. In the same way, for each ultrasonic transducer element 1, one of the plurality of second electrodes 32 is ~~inserted~~ positioned between the outer and inner sides 21,22 of the membrane. The plurality of first electrodes 31 and the plurality of second electrodes 32 are connected with a voltage source by electrically conducting paths in the base and the membrane respectively. The plurality of first electrodes 31 can also be ~~installed~~ positioned on the upper side 11 or the lower side 12 of the base 10, and the plurality of second electrodes 32 can also be ~~installed~~ positioned on the outer side 21 or the inner side 22 of the membrane 20.

In the arrangement just described, the support 14 has a relatively large height, consequently, the distance between the first and second electrodes 31, 32 is relatively large, providing a relatively thick insulating layer and allowing for a large vibration amplitude of the membrane, furthermore reducing the steps needed for manufacturing the silicon base. Between the first and second electrodes 31,32, a relatively large amount of electrical energy is stored for driving the membrane 20 to be converted to mechanical energy for vibrations.

Referring to Fig. 2, various ultrasonic transducer elements are distributed with ~~equal~~ repeating mutual distances. Using soft material for the base 10 and a large number of ultrasonic transducer elements results in a high amount of mechanical energy for vibration.

Referring to Figs. 3 and 4, with the base 10 being flexible, high transmission of ultrasonic waves are attained. Coupling to air and transmitting energy, attenuation is compensated and a high response by ~~any type~~ various configurations of sensor is achieved.

The present invention discloses a flexible microelectromechanical ultrasonic transducer, using conventional height-width-depth relations, and microelectronic control,

produced with MEMS processes (e.g., but not limited to DRIE (Deep Reactive-Ion Etching)- and LIGA (Lithographic Electroplating and Molding)-like technology), comprising a micro-array, flexible supports and transducers and being connectable with all types of external or integrated electric circuits.

page 4, line 20:

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